Journal of Water Resource and Protection, 2022, 14, 456-473
https://www.scirp.org/journal/jwarp
ISSN Online: 1945-3108
ISSN Print: 1945-3094

Sizing of a Wastewater Treatment System of the Center of Ngoundiane of the Alioune DiOP University of Bambey, Senegal

Ibrahima Niane[1*], Amadou Diao[2], Fakoro Souleymane Dia[1], Senghane Mbodji[1]

[1]Research Team in Renewable Energies, Materials and Laser of Department of Physics, UFR SATIC, Alioune DiOP University of Bambey, Bambey, Senegal
[2]Laboratory of Semiconductors and Solar Energy, Department of Physics, Faculty of Science and Technology, Cheikh Anta Diop University, Dakar, Senegal
Email: *nianeibrahima70@gmail.com

How to cite this paper: Niane, I., Diao, A., Dia, F.S. and Mbodji, S. (2022) Sizing of a Wastewater Treatment System of the Center of Ngoundiane of the Alioune DiOP University of Bambey, Senegal. *Journal of Water Resource and Protection*, **14**, 456-473.
https://doi.org/10.4236/jwarp.2022.146024

Received: April 4, 2022
Accepted: June 19, 2022
Published: June 22, 2022

Abstract

In our center where a lot of water is used for watering and cleaning the classrooms, the management of wastewater as a resource can be a real opportunity. The main objective of this research is to size and determine the effectiveness of natural treatments of the wastewater treatment system composed of a septic tank and a treatment plant which would be installed in site Ngoundiane of Alioune DiOP University, in Bambey, Senegal. Overall, we noted that the sized septic tank dimensioned in our study allows the efficient settling of wastewater which depends on the flow point ratio and useful settling surface area that must be lower than the upward speed that corresponds to 0.8 m/h. The sizing of the septic tank led us to obtain a useful capacity of 88 m^3 and a horizontal surface of 44 m^2 with a height of 2 m. The ratio between the flow of the wastewater received and the upward speed is 0.17 m/h and is significantly lower than the recommended speed. In addition, the station will be able to eliminate 80.418% of the Biochemical Oxygen Demand (BOD), 75.522% of the Chemical Oxygen Demand (COD), 92.385% of Suspended Solid (SS) and 43.427% of Nitrogen compounds.

Keywords

Wastewater, Septic Tank, Sanitation, Treatment Plant, Irrigation

1. Introduction

Sanitation is a technique for removing wastewater through hydraulic channels. It is a tool that allows fighting against environmental pollution, diseases, floods, etc. [1]. Indeed, many African countries are confronted with the difficulties related to the use of wastewater thanks to the inadequacy of conventional treatment systems due to their colossal expenditure of operation and maintenance but also of the difficulty of ensure their long-term maintenance. It is in this sense that it is important to innovate in this field by providing reliable purification techniques adapted to our countries. This is how planted filters, due to their direct acceptance of domestic wastewater without the need for prior settling, remain the most used industrial unities for recycling the wastewater and to accommodating hydraulic loads from unit networks [2] [3]. These industrial unities are ecological, economical and efficient treatment methods that are considered as sustainable strategies for water resources. In addition, the adaptation of planted filters induces the use of local materials [4]. In developed countries such as France, the treatment of wastewater by planted filters is becoming an indisputable technology due to their satisfactory results. The evaluation of the performance of this technology would be relevant especially in our areas where the associated mean monthly evapotranspiration is estimated to 407 mm while the mean internal temperature of the septic tanks varies between 27.5˚C and 34.5˚C depending on the hours of the day and of the month considered. To fight against filter malfunction it is necessary of size for these wastewater treatment plants which are dimensioned empirically like the national center for agricultural machinery [2]. It is in this sense that the environmental Life Cycle Analysis (LCA) model is one of the assessment methods capable of quantifying and avoiding the transfer of organic pollutants into the receiving environment [5]. Thus, the sizing of these installations strongly depends on the data of the population (from 50 to 1000 inhabitant equivalent (IE), even 2000 (IE), the consumption of drinking water, the discharge of wastewater and the acceptable organic load expressed in filter area per inhabitant equivalent (IE) [2] [3] [4] [5] [6].

Ultimately, our research aims to size a wastewater treatment plant in the center of Ngoundiane and to determine its effectiveness of natural treatments. In materials and methods, we present the composition as well as the models used to size our experimental device.

2. Materials and Methods

Our future treatment plant will be mainly equipped, in addition to the planted filters (vertical and horizontal), a screen, manholes and a septic tank for the pretreatment of wastewater.

2.1. The Raw Wastewater Acquisition Pit

The septic tank is a sanitation system that aims to protect human health and the environment by preventing the discharge of wastewater into nature.

2.1.1. Performance of the Settling Tank (Septic Tank)

For a home where the population does not exceed 150 IE, the all-water septic tank is no longer used to ensure the primary treatment of domestic wastewater.

The septic tank retains solids to prevent the downstream filter malfunction by the gravity separation of the solid particles between the flotation and the sedimentation.

The minimum value of this speed is 0.8 m/h [7]. According to the literature search, the time should be equal to three days to allow sufficient preliminary processing [8].

The user model of septic tank is considered as an ideal settle in which settling is based on the principle that in free settling, the retention of a particle essentially depends on the horizontal surface available. It is presented in **Figure 1**.

V_0 is the falling speed of particles and V_x corresponds to the particle flow velocity.

The settling can be defined as a physical process which consists of separating particles according to their density. It also helps to remove suspended particles from the water to be treated.

To better explain this phenomenon, we consider a septic tank that has a length L_u, a width l_u and a height H_u. In order for a particle to remain in the septic tank considered as an ideal settler, Equation (1) must be satisfied.

$$V_0 > H_u/t \tag{1}$$

The hydraulic retention time is calculated based on the effective length and the flow velocity of the effluent.

Let us determine the hydraulic retention time.

$$V_x = L_u/t \tag{2}$$

Hence, we can have

$$t = L_u/V_x \tag{3}$$

Knowing that:

$$V_x = Q_{maxn}/H_u \times l_u \tag{4}$$

By replacing the flow velocity of the effluent by its formula in Equation (3), we

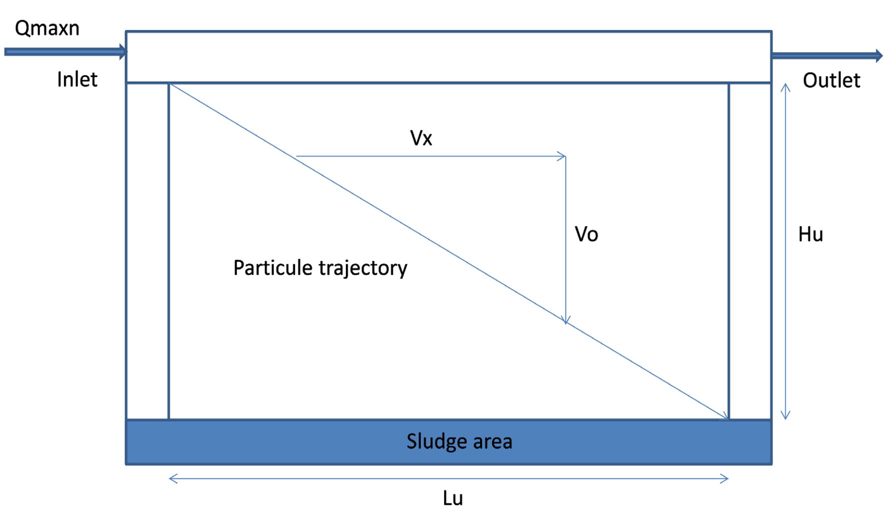

Figure 1. Schematic of an ideal HAZEN settling tank [9].

obtain:

$$t = \left(H_u \times L_u \times l_u\right) / Q_{maxn} \tag{5}$$

Introducing Equation (5) into Equation (1), we obtain:

$$V_0 > H_u / \left(H_u \times L_u \times l_u\right) / Q_{maxn} \tag{6}$$

Hence

$$V_0 > Q_{maxn} / \left(L_u \times l_u\right) \tag{7}$$

where ($L_u \times l_u$) is the useful surface (S_u) of the septic tank.

S_0 the settler tank is effective if the relation (8) is verified:

$$V_0 > Q_{maxn} / S_u \tag{8}$$

With:

Q_{maxn}/S_u is the noted flow velocity [9].

2.1.2. Sizing of a Septic Tank

The sizing of a septic tank that has the functions of settling and digestion of sludge depends on the latter. Contrary to the first function (corresponding to the settling function), the septic tank can be likened to a settling tank. The calculation of this function amounts to determining the horizontal surface of the pit starting from a speed of rise chosen because it is related to the hydraulic residence time (t) allowing the septic tank to retain all the particles in suspension [10].

In effect, the sizing of a septic tank takes into account several variables such as the volume of the settling tank, the useful surface, the hydraulic retention time, the rate of rise, etc. [11].

The average volume V_u of the retention basin is obtained from the wastewater inlet flow rate and the retention time. The input flow represents the unit flow rejected by the person (Q_{wwpd}). Since in the bibliographical review, the hydraulic retention time is between one and three days, a retention time of two days is considered to fight against any overflow of wastewater. The capacity of the pit is obtained by Equation (9).

$$V_u = Q_{wwpd} \times N_{pex} \times t \tag{9}$$

With:

$$Q_{wwpd} = Q_{mexd} / N_{pex} \tag{10}$$

Q_{mexd} corresponds to exact average daily flow,

N_{pex} is the number of people usually attending the center.

The total volume of the pit is calculated taking into account the space occupied by the gases resulting from the anaerobic fermentation (approximately 30 cm) [12]. The volume occupied by these gases is expressed as:

$$V_{fre} = L \times l \times 0.3 \tag{11}$$

The total volume (V_T) of an all-water pit is the sum of the useful volume of the pit and that between the water and the slab is written as:

$$V_T = V_u + V_{fre} \tag{12}$$

The useful settling surface (S_u) can be defined as the total surface occupied by the water inside the pit. As we have previously mentioned in the text, a septic tank is much more settable if its surface is large. This settling function also gives an idea of the other parameters accompanying the wastewater treatment process. The sizing of the pit depends on both the useful volume (V_u) and the useful height of the pit but also on the available space.

$$S_u = V_u / H_u \tag{13}$$

This equation illustrates that the pits that have an identical useful volume, the one whose useful height is lower is more efficient in the field of settling.

Beyond, the domestic wastewater comes from the various agglomerations of the center, *i.e.*, the sanitary, the showers and the cabinets. These are waters which have been altered by man. The wastewater flow rate noted (Q_{wwad}) represents 80% of the drinking water flow rate consumed. The quantity of wastewater discharged depends above all on the population living in the center. It is important to point out that a certain number of students live in the village but spend most of their time in the center due to catering, studies, sports and also bathing because of the lack of water that reigns in the commune.

The exact daily average flow rate of wastewater discharged is obtained from this flow rate. It is given by Equation (14) below.

$$Q_{mexd} = Q_{wwad} \times N_{pex} / N_{tp} \tag{14}$$

and:

$$Q_{mexd} = Q_{wwpd} \times N_{pex} \tag{15}$$

With:

Q_{wwpd} means the average wastewater discharge rate per person per day,

N_{tp} corresponds to total number of people that the center should contain.

The peak flow also called the design flow is the maximum normal flow (Q_{maxn}) that passes through a pipe when the flow takes place in full section. It can be calculated as a function of the average daily flow rate of discharged wastewater and the peak factor (F_p) [13]. It is presented in Equation (16) below:

$$Q_{\max n} = Q_{mexd} \times F_p \tag{16}$$

and:

$$F_p = 1.5 + 2.5 / \sqrt{Q_{mexd}} \tag{17}$$

where 1.5 is a parameter that expresses the lower limit and 2.5 corresponds to the growth value.

Depending on the climatic conditions that differ to the months of the year, the average daily discharge discharged is variable. To fight against the overflow of water in the septic tanks, we will calculate the normal maximum daily flow discharged by the center called the point flow or even the project flow corresponding to the flow that enters the treatment system. To estimate the hydraulic head, the flow rate projected is used to be obtained in 2040 to avoid all overflows. Thus we have:

$$Q_{maxn}\left(\mathrm{m}^3/\mathrm{d}\right)2040 = Q_{maxn}\left(\mathrm{m}^3/\mathrm{h}\right)\times 24 \quad (18)$$

2.2. Study of the Treatment System

2.2.1. Screening of Protection [6]

Screening allows the protection of the lifting pumps, the retention of the coarsest materials such as coffee filters, condoms, dressings, stones and waste of all kinds that could cause the malfunction of the station. There are two types of screen, which are the manual screen and the automatic screen equipped with a rake and a comb driven by a motor, respectively, for sweeping the grille. In the rest of our work, we will work with a screen with manual cleaning because of the financing costs, high average maintenance.

The grid will be constructed with rectangular bars, in galvanized steel 10 mm thick and with a spacing of 12 mm between the bars. The inclination of the grid is between 20˚ and 45˚ from the vertical. In our study, we choose the value of 45˚ with respect to the vertical to prevent solids from going by over the grid.

The pressure losses (ΔH) are evaluated by the following formula:

$$\Delta H = \gamma \times \left(E/e\right)^{4/3} \times \left(V_{\max}^2/2\times g\right)\times \sin\beta \quad (19)$$

where:

γ is the form factor and is equal to 2.42 for a straight pipe,

β corresponds to angle of inclination and is equal to 45˚,

E is defined as the thickness of the bars,

e is the distance between the bars,

$V_{\max}$ is the speed of the effluent through the screen that is estimated at 1.2 m/s for a manual screen. It is also important to set up a bypass channel for diverting the liquid to bypass the screen in the event of clogging.

Table 1 summarizes the characteristics of our grid.

The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anti-cipate your paper as one part of the

Table 1. Characteristics of our grid.

Grid tilt	45˚
Bar thickness	10 mm
Free space between bars	12 mm
Velocity through the grid	1.2 m/s
Form factor	2.42
Pressure drop	118 mm

entire journals, and not as an independent document. Please do not revise any of the current designations.

2.2.2. Processing Configuration and Filter Working

The experience of planted filters is a recent treatment technique for domestic wastewater that has not yet been spread in our countries. It is an eco-innovative system that is associated with the climatic, environmental and economic context of emerging countries, mostly belonging to the tropical zone. This climate is favorable to the biological and plant activity of the environment, allowing it to have a very good purifying capacity of organic matter. This is a method that requires little financial means for its installation and maintenance. The filter model adopted on our center is composed of vertical filters for the first stages and horizontal filters for the second stages. Each floor includes a top layer, a transition (middle) layer and drainage one. The station is preceded by a septic tank and a receiving manhole at the entrance and exit of the wastewater treatment plant.

To facilitate the evacuation of treated water at the bottom of the filters, Arthur IWEMA and *et al*. [13] are provided a slope of 10% and to facilitate the infiltration of water into the filter, it is necessary to study the granular profiles and material height.

Starting from this fact, the gravel and the sand used in the filters must be of good quality and checked after each delivery to ensure the correct functioning of the filter. In most of these treatment systems, the first and second stages consist of 3 successive layers [2].

As regards the first stage, the superficial receiving layer (or filtering layer) with a minimum thickness of 30 cm is filled with fine gravel with diameters between 2 and 8 mm. This layer is followed by the transition layer. It is filled with gravel with a diameter ranging from 5 to 20 mm and a thickness of 10 to 20 cm. The last layer of this stage, called the drainage layer, is filled with gravel with a diameter of 20 to 60 mm and a thickness identical to the previous one.

Then the filter layer of the second stage is filled with sand having a diameter between 0.25 and 0.40 mm and a minimum thickness of 10 to 60 cm. The intermediate and drainage layer have the same thickness as the first stage drainage layer. They are filled with gravel with respective diameters of 3 to 20 mm and 20 to 40 mm.

2.2.3. Sizing of the Domestic Wastewater Treatment System (Planted Filters)

First, we are interested in the surface of the treatment. In the literature there aren't any equations for sizing filters. The sizing is based on empirical relationships which are based only on experience.

This is how the sizing of our installation is done by the indirect method due to the non-existence of the station. It depends on the definition of the Inhabitant Equivalent (IE).

In fact, to properly size the filters, it is necessary to take into account the number of inhabitants connected rather than the flow of the organic load (BOD, COD): 300 g COD/m^2/d, 150 g SS /m^2/d, 25 to 30 g NKT m^2/d, hydraulic head of 0.37 m/d for each first stage filter and 120 g COD/IE, 60 g SS/IE, 10 to12 g NKT/IE, 150 l/IE for each second stage filter [2] [3].

In our case, the surface required for each filter of the first stage is 1.2 m^2/IE and 0.8 m^2/IE for each filter of the second floor because the organic loads contained in the wastewater of Ngoundiane are adequate with this sizing [3].

According to the European direction of May 21, 1991, the inhabitant equivalent constitutes the biodegradable organic load with a BOD of 60 g O_2/d. In domestic workers, one inhabitant provides the biodegradable organic load with a BOD of 40 g O_2/d [8]. So a calculation with the inhabitant equivalent (IE) constitutes an over-sizing of 66.6% on the installation. This will allow us to fight against hydraulic overloads that is linked to tropical rains and against variations in organic load. Considering a population, the organic load in g O_2/d provided by this population is evaluated by:

$$\begin{cases} H_b \text{ provides } 40\text{ g O}_2\text{/d, and } N_{pex} \text{ provides } Y \text{(in g O}_2\text{/d)} \\ \text{We then get the following equation:} \end{cases}$$

$$Y = N_{pex} \times 40 \text{ g O}_2/\text{d} \tag{20}$$

The inhabitant equivalent corresponding to the population of Ngoundiane site is calculated by the following equation:

$$\begin{cases} \text{One IE provides } 60\text{ g O}_2\text{/d} \\ \text{and } \kappa \text{ provides } Y \text{(in g O}_2\text{/d)} \end{cases}$$

Hence:

$$\kappa = Y/60 \tag{21}$$

So, the total area of the filter is calculated by:

$$\begin{cases} \text{One IE provides 2 m}^2\text{/ IE} \\ \text{and } \kappa \text{ provides } S_t \end{cases}$$

Hence:

$$S_t\left(\text{m}^2\right) = 2\text{ m}^2/\text{IE} \times \kappa \tag{22}$$

where:

$$S_1\ (\text{m}^2) \text{ is equal to } 1.2\text{ m}^2/\text{IE} \times \kappa \tag{23}$$

$$S_2\ (\text{m}^2) \text{ runs to } 0.8\text{ m}^2/\text{IE} \times \kappa \tag{24}$$

With:

S_t corresponds to the total filter area,

H_b being the inhabitant,

N_{pex} corresponds to the population,

Y is the organic load,

κ is equal to the inhabitant equivalent corresponding to the population of

Ngoundiane site, l corresponds to the liter, and d is the day.

Secondly, we will study the daily volume of wastewater acquired by the filter. The capacity of wastewater to be recycled by a filter depends on the daily quantity of effluent per inhabitant equivalent and day by day. The volume treated per inhabitant equivalent is estimated to be 0.15 m^3/IE/d.

Hence

$$V_{eff} = \lambda \times 0.15\ \text{m}^3/\text{IE}/\text{d} \tag{25}$$

About the hydraulic load (Q_h), it can be defined as the quantity of wastewater distributed over a surface of a filter during a given time. Also, this is the flow rate of the pump [3]. It depends on the surface of the filter but also on the flow of waste water discharged by the center.

$$Q_h\left(\text{m}^3/\text{m}^2/\text{d}\right) = V_{eff}/S_1\left(\text{m}^2\right)\ \ [8] \tag{26}$$

Moreover, the choice of a pump intended to supply the station depends on the manometric head and the pumped water flow. The hydraulic pumping power (w/h) is given by the Equation (27) [14].

$$P_{hyd} = \left(\rho \times g \times q_h \times h_T\right)/3600 \tag{27}$$

With:

$$q_h = V_{eff}/24 \tag{28}$$

With:

q_h (m^3/h) is the pumped water flow, *i.e.*, the capacity of water to be recycled by a filter,

ρ is the water volumic mass,

g corresponding to the constant of gravity,

h_T (m) corresponds to the manometric head.

2.2.4. Treatment Performance of the Station

A treatment system must be designed in such a way that it manages to reduce the applied pollutant load and allow the discharge of treated water that meets the standards for discharge into the natural environment. Thus, the purification performance of a plant depends on its ability to remove the organic load from raw wastewater. In this sense, the used macrophytes have not only well adapted to the polluting load applied, but they have presented very interesting reduction rates. Indeed, Lombard Latune R. & Molle P. [8] has tried to make an inventory of local plants (aquatic, semi-aquatic and terrestrial) likely to participate in efficient wastewater treatment processes at a lower cost but also technically adapted to the tropical climate.

On this point, the reduction in coliforms is given by the formula (29) below [6]:

$$N/N_0 = 1/\left(1 + K_t \times t_s\right)^2 \tag{29}$$

$$K_t = 2.6 \times 1.19^{(T_m - 20)} \tag{30}$$

T_m is the average temperature of the wastewater from septic tank of our study center;

t_s corresponds to the residence time of water in the filter.

Also, the output concentration of some wastewater parameters can also be assessed by several methods.

The reliability of a station is the probability of achieving adequate performance over a defined period. To achieve this, the treatment system must comply with an average concentration at the outlet that is lower than that set by the Senegalese wastewater discharge standard. This average concentration up to 90% of the operating time is evaluated by the following Equation (31) [15].

$$C_{a.out} = C_{reli} \times C_{rej} \tag{31}$$

With:

$C_{a.out}$ means the average output concentration of the considered effluent parameter;

C_{reli} is the reliability coefficient;

C_{rej} corresponds to the concentration of the rejection standard of the parameter considered.

The coefficient of reliability is developed by DJEDDOU Messaoud and *et al.* [15] to define a target concentration to be reached in order to guarantee a fixed release level.

The methodology of the coefficient of reliability plays a preponderant role in the treatment system because it makes it possible to evaluate the level of reliability of filters planted with the vegetation. However, this coefficient depends on the reliability rate and the coefficient of variation of the system. The evaluation of the performance of the wastewater treatment system is facilitated by the study of R. Lombard-Latune and *et al.* [16].

To assess the performance of our station, we have set, for each of the physicochemical parameters, a well-defined reliability rate and coefficient of variation because it is assumed that there is no malfunction in the treatment process. The reliability coefficient is obtained from the reliability rate and the other variation coefficient called the correction coefficient given by the circular of May 22, 1997 relating to non-collective sanitation. The corrective coefficient is set to 0.3 because we consider the Ngoundiane site as a school (day school) or similar [8]. In addition, the hydraulic load applied to the filter is sufficient to ensure a good distribution of wastewater over its entire surface.

On the other hand, the choice of reliability rate for the nitrification of nitrogen is facilitated by the use of coarse sand and fine sand constituting the different layers of our filter [17].

The concentrations obtained before and after the filtration of the various organic parameters led to the determination of the yield (R) of the treatment system. It is evaluated by the relation (32) below [18]:

$$R = \left(\left(C_{a.inl} - C_{a.out} \right) / C_{a.inl} \right) \times 100\% \tag{32}$$

With:

$C_{a.inl}$ corresponds to the concentration of the component at the inlet of the filter.

3. Results

3.1. The Settling Tank (Septic Tank)

The interpretation of Equation (6) allows us to evaluate the importance of the surface on the settling of the sludge. This equation illustrates that as the useful settling surface increases, the rate of climb decreases. This increases the retention capacity of the sludge in the septic tank. The equation also shows us that the retention of particles depends on the falling and rising velocities of the particles. A particle whose falling velocity is greater than the rising velocity remains in the pit.

In a nutshell, we will say that a pit is much more efficient if the settling surface is large horizontally. In fact, the correct sizing must take into account the flow-point ratio and the useful settling surface area, which must be less than the upward speed (0.8 m/h) [7].

Table 2 shows the performance of the different pits on the settling of domestic wastewater of the center of Ngoundiane.

With S_1, S_2, …, S_5 are the septic tanks with various sizes;

m^2 (square meter) corresponds to unit of area;

m^3/h (cubic meter per hour) being the unit of flow;

m/s: meter per second. It is the unit of speed.

The results obtained in Table 2 shown that the account flow-point ratio and useful settling surface area is less than the upward speed (0.8 m/h). This shows that all these pits are efficient and that are well sized.

As to the capacity of the septic tank, the average volume is estimated to 88 m^3.

In effect this volume is sufficient to receive all the domestic wastewater from the center because it is obtained by the project flow.

As for the project flow, the peak flow is the design flow that also represents the flow or maximum water through the pipe.

As mentioned above, the wastewater flow rate discharged by the Ngoundiane center is obtained from the drinking water flow rate consumed by the total population of the center. However, not all the population lives inside the center,

Table 2. Performance of the septic tanks (ST).

Septic tanks	S_u (m^2)	Q_{maxn} (m^3/h)	Q_{maxn}/S_u (m/s)
S_1	88	7.37	0.08
S_2	73.3	7.37	0.10
S_3	58.7	7.37	0.12
S_4	48.9	7.37	0.15
S_5	44	7.37	0.17

there are some people who live in the village. To know the exact average and maximum flow rate released by the population living in the center, we must first estimate the daily wastewater flow rate released per person. Then knowing this flow and the number of people who spend most of their time at the center, we calculate the average daily flows exactly rejected. Finally, we estimate the peak flow rates corresponding to the project flow rate which also depends on the evolution of the population per year.

These rates are shown in Table 3.

With m^3/d (cubic meter per day) corresponds to the unit of the flow;

l/s (liter per second) is the unit of the flow.

It is noted that the average daily flow released by the center increases from year to year. We can say that this proliferation is due to the increase of the population that enters the center each year.

In Figure 2 we present the variation of the flow according to the population.

This figure shows that the flow of wastewater discharged increases according to the proliferation of the student population, hence the need to properly size the treatment system to fight against any overflow of water.

The sizing of a septic tank should also pay attention to provide the inlet and outlet devices that must be designed so as to allow distribution of the liquid without creating a short circuit in the tank or too much suspension of the pipes sludge already accumulated.

In many cases, the septic tank is partitioned at the rate of 2/3 for the first compartment and 1/3 for the second, even if this compartmentalization is not

Table 3. Estimation of discharged domestic wastewater flow rates.

Years	2019	2022	2025	2028	2031	2034	2037	2040
N_{pex}	216	223	231	239	247	256	265	274
Q_{mexd} (m^3/d)	39.164	4.519	41.924	43.370	44.871	46.423	48.029	49.690
Q_{mexd} (l/s)	0.453	0.468	0.485	0.502	0.519	0.537	0.556	0.575
F_p	5.213	5.150	5.088	5.028	4.969	4.910	4.853	4.796
Q_{maxn} (m^3/h)	6.527	6.753	6.987	7.228	7.478	7.737	8.004	8.281
Q_{maxn} (l/s)	1.813	1.875	1.940	2.008	2.077	2.149	2.223	2.300

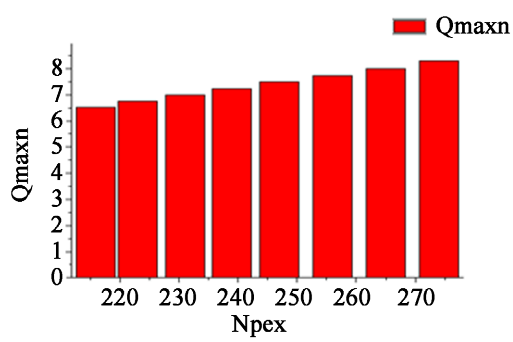

Figure 2. Flow variation as a function of the increase in the population of the center.

justified from the point of view of settling [19]. The effluent leaving the septic tank must undergo treatment before being discharged.

But in general in Senegalese universities, this water is directly discharged into nature and some in the loosing wells which are deep pits filled with river rubble.

These wells are considered to be treatment devices for the water coming out of the septic tank but in reality they only pollute the phreatic tablecloth. **Table 4** below shows the different sizing scenarios for our pit. These dimensions were chosen according to the useful depth of the septic tank (1 m, 1.2 m, 1.5 m and 1.8 m) to see the impact of the depth on the useful surface. The lengths L_1 and L_2 are obtained by the partition at the rate with 2/3 for the first compartment and 1/3 for the second.

F_1, F_2, F_3, F_4, F_5 correspond to the different septic tanks who are installed in the Ngoundiane center;

H_u is the total height in meter (m);

L_1 and L_2 are respectively the lengths of the first and second septic tank comportment.

The importance of these different values was shown in this table on the location, the land use and the shape of the pits depending on the space available in the study environment.

3.2. Domestic Wastewater Treatment Plant

The filters planted with plants are considered to be ecological, economical and efficient treatment systems for wastewater.

In this regard, the pressure drop (ΔH) across the grid is estimated to 0.118 m according to our calculations. This is less than the allowable pressure drop which corresponds to 0.150 m and is also greater than that found by Lamyae BOUGHANZAI, Mohammed MERZOUKI, Ahmed OUZINA [6].

In effect, these treatment systems require little space for their installation. The results obtained by the calculation filters surface are shown in **Table 5**.

S_1 is the area of the first compartment;

S_2 being the area of the second stage;

g O_2/d (gram of oxygen per day) corresponds to the unit of the organic load.

We noted that there areas are greater than 100 m^2. According to the literature an area greater than 100 m^2 can be subdivided into two or three beds [20]. So, we

Table 4. Different dimensions of the installations (septic tanks (ST)).

S_T	V_T (m^3)	V_u (m^3)	H_T (m)	H_u (m)	S_u (m^2)	L_u (m)	l_u (m)	L_1 (m)	L_2 (m)
F_1	114	88	1.3	1	88	11	8	7.3	3.7
F_2	110	88	1.5	1.2	73.3	10.8	6.8	7.2	3.6
F_3	105.6	88	1.8	1.5	58.7	10.6	5.5	7.1	3.5
F_4	102.7	88	2.1	1.8	48.9	10.4	4.7	6.9	3.5
F_5	101.2	88	2.3	2	44	10.2	4.3	6.8	3.4

Table 5. Filter surfaces obtained.

N_{pex}	216	223	231	239	247	256	264	274
Y (g O_2/d)	8640	8920	9240	9560	9880	10240	10560	10960
λ	144	148.67	154	159.33	164.67	170.67	176	182.7
S_t (m^2)	288	297.3	462	318.7	329.3	341.3	352	365.3
S_1 (m^2)	172.8	178.4	184.8	191.2	197.6	204.8	211.2	219.2
S_2 (m^2)	115.2	118.9	123.2	127.5	131.7	136.5	140.8	146.1

are going to build two beds, each of it has an area equal to approximately 100 m^2 for each of the first compartments (vertical filter) and a surface bed of 100 m^2 for the second stage (horizontal filter).

Next, the capacity of water to be recycled by our filter is estimated at 24.375 m^3/d. And the hydraulic load (Q_h) found in our study is:

$$Q_h = 0.125\ \mathrm{m^3/m^2/d} = 125\left(\mathrm{l/m^2/d}\right).$$

This flow is sufficient to ensure the distribution of water over the entire surface but also it allows the self-cleaning of the supply pipes since it is lower than that found in the study by Pascal MOLLE and *et al.* [2] (Q_h = 0.37 m·d^{-1}). This hydraulic load is also greater than that found by T. Fonkou, M.F. Fouteh, M. Djousse Kanouo, Amougou Akoa [18] which is 2×10^{-2} m·d^{-1} and applied to the filter planted which contributes to the reductions of 80% for conductivity, 60% in COD, 79% for suspended solids, 80% in total nitrogen and 50% for total phosphorus.

Also, the experience of planted filters requires low electricity consumption with an average hydraulic pumping power of 12.177 W/J.

As part of the performance of the domestic wastewater treatment system, **Table 6** represents the results obtained in our study on the quantity of coliforms eliminated by the treatment plant.

The results represented in **Table 6** clearly show a decrease of the pathogens in the treated wastewater. These results illustrate the performance of plant filters in tropical areas such as the Ngoundiane site, which is always sunny.

In **Figure 3**, we represent the concentration of coliforms versus the temperature.

These showed results in **Figure 3** show that, for the temperatures between 27˚C and 35˚C, the concentration of the coliforms decreases with temperature proliferation. In other words, the elimination of coliforms increases with this temperature. The mean exit concentration of coliforms, 8.821×10^{-9}, is significantly lower than that set by the World Health Organization (WHO) and which is equal to 10 CFU/ml of water. Our value is lower than that found in the study by Lamyae BOUGHANZAI, Mohammed MERZOUKI, Ahmed OUZINA [6] which is estimated to 0.0359.

Table 6. Quantity of coliforms eliminated by the treatment plant.

Hours	8h30	10h30	12h30	14h30	16h30	18h30
T_m (˚C)	29.5	28.2	28	27.5	30	34.5
K_t	45,702.81	10,526.08	8397.74	4774.22	80,390.19	12,958,194.24
N/N_0	1.20×10^{-10}	2.26×10^{-9}	3.54×10^{-9}	1.10×10^{-8}	3.87×10^{-11}	1.49×10^{-15}

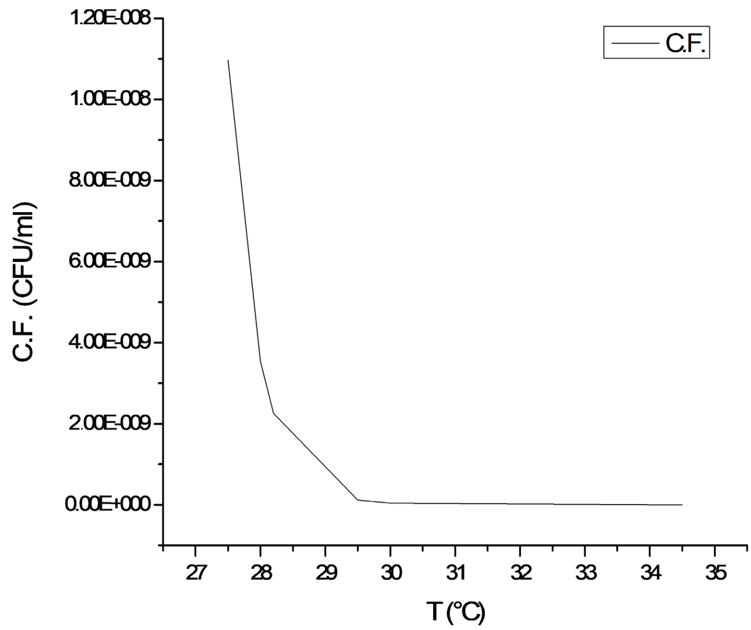

Figure 3. Variation in coliform concentration as a function of temperature.

Table 7. Minimum treatment performance expected for the parameters (BOD, COD, SS, NKT, and P).

Parameters	$C_{a.int}$ (mg/l)	$C_{a.out}$ (mg/l)	R (%)
COD	661.82	162	75.522
BOD	330.92	64.8	80.49
SS	275.76	21	92.384
NKT	55.15	31.2	43.427
P	5.51	-	-

After, we show the results obtained from the treatment performance for the polluting parameters. In **Table 7**, we represent the minimum treatment performance for the polluting parameters that are the BOD, the COD, the SS, NKT and the P.

In **Figure 4**, we illustrate the variation of chemical parameters at the inlet and outlet of the treatment plant to be installed.

As it can be seen in **Figure 4** obtained with Excel, we noted the difference between the gross load received by the treatment system and the load of the treated effluent noted in the table above.

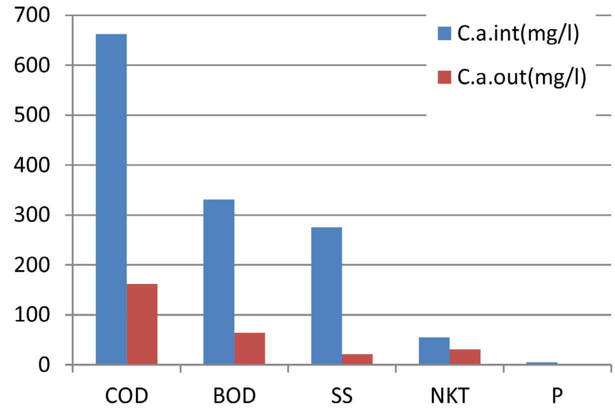

Figure 4. Variation of chemical parameters at the inlet and outlet of the treatment plant to be installed.

We remarked towards **Figure 4** that the treatment of carbon pollution is satisfactory with a significant reduction in pollutant loads.

At the outlet of the treatment system basin, there is a decrease in the suspended solids (SS) concentration compared to that obtained at the inlet. The found value (21 mg/l) is lower than that set by the discharge standard in Senegal (50 mg/l). This drop in SS concentration may be due to the retention of solids at the surface of the filter. The yields found in the work of Morvannou, Forquet N., Michel S., Troesch S., Molle P. [21] are 80%. These results are lower than that we obtained and estimated to 92.385%.This difference can be explained by the previous passage of wastewater through a screen which will reduce coarse solids.

Analysis of the biochemical oxygen demanded (BOD) results illustrate the decrease in its concentration at the outlet of the filter bed. It is 64.8 mg/l and is lower than that set by the standard required by Senegalese legislation on the discharge of wastewater into receiving environments such as watering green spaces. This reduction can be explained by the deterioration of the biodegradable organic matter by the microorganisms which attach themselves to the roots of the plants to develop, by their retention in the SS. The obtained yield evaluated to 80.418% is high. It is comprised in interval's results of that of Catherine Boutin, D. Esser, Pascal Molle, A. Lienard, [22] which stipulate that the yield of BOD can vary from 70% to 90%.

The obtained results show us that the concentration of chemical oxygen demanded (COD) decreases in the filtrates compared to that recorded at the entrance to the station. This value (162 mg/l) is lower than that of the Senegal discharge standard. The observed decrease is linked to the physical retention of organic matter from wastewater in filters and its aerobic oxidation by microbial flora thanks to plants supplying them with oxygen through photosynthesis. The purification efficiency for COD recorded is 75.522%. It is substantially equal to that found by Catherine Boutin, D. Esser, Pascal Molle, A. Lienard, [22] which are equal to 75%.

As with the parameters mentioned above, the nitrogen concentration has dropped. This drop may be explained by the fact that plants need some nitrogen to develop. The nitrogen yield is 43.427% and is upper than that found by Boutin Catherine, D. Esser, Pascal Molle, A. Lienard [22] (37%). The poor nitrogen removal can be explained by the formation of nitrates from the oxidation and decomposition of organic materials. Nitrification occurs in the aerobic upper part of the filter. The phosphate output concentration is not calculated because this parameter met the standard achieved for wastewater discharge.

4. Conclusions

Throughout this study we tried to develop the solutions related to the problems of residues from septic tanks, particularly their sizing and performance. Indeed, it has been shown that the establishment of a treatment system (planted filter) at a lower cost is indeed possible because of the purification yields obtained but also of the reduced space occupied by these treatment techniques.

Our study also made us understand that the plant filters provide solutions to problems that haven't been mastered for a long time such as soil influence, phosphorus, etc. These types of treatment are emerging as flagship sectors for small communities (non-collective sanitation) because they present significant purification yields for organic loads. Overall, we can say that the station will be able to remove 80.418% of BOD, 75.522% of COD, 92.385% of suspended solids and 43.427% of nitrogen compounds.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Othman, B. and Rafik, B. (2019) Sizing of Sewerage Network from the City Rabta West (w. Jijel). End of Study Project, Faculty of Science and Technology, University of Mohammed Sedik Ben Yahia-Jijel, Department of Civil and Hydraulic Engineering, 21-07, 3-4.

[2] Molle, P. (2012) Filters Planted with Reeds: Evolution of Research and Current Trends. *Science Water and Territories*, **9**, 24-31.

[3] Sylvain, J., Boutin, C., Bouvard, V., *et al.* (2007) Filters Planted with Reeds. Framework Guide for a Book of Particular Technical Classes (CCTP), 25-51.

[4] Kadouche, S., Hammoum, H., Ghedamsi, H. and Si Tahar, L. Assessment of Purifying Performance of a Wastewater Filtration Basin-Case. *Journal of Water Science*, **31**, 387-398. https://doi.org/10.7202/1055596ar

[5] Risch, E., Boutin, C., Roux, P. and Heduit, A. (2012) Life cycle Analysis of Sanitation Systems: A Complementary Decision Support Tool. Water and Territory Sciences, INRAE, 82-90.

[6] Boughanzai, L., Merzouki, M. and Ouzina, A. (2012) Sizing of a Natural Lagoon-Type Wastewater Treatment Plant at the Ain Cheggag Center. FES, Morocco, No. 2, 29-33.

[7] Alexandre, O., Boutin, C., Duchéne, P. and Lagrange, C. (1998) Purification Fliers Adapted to Small Communities. *FNDAE Technical Document*, No. 22, 1-96.

[8] Lombard Latune, R. and Molle, P. (2017) Constructed Wetlands for On-Site

Wastewater Treatment in the Tropics. Guidelines on Sizing Tropicalized Systems, French Biodiversity Agency, Guides and Protocols Series. 72.

[9] Edeline, F. (1992) Theory and Technology of Reactors. In: CEBEDOC, Ed., *Physico-Chemical Purification of Water*, Liège/Lavoisier Tec, Paris, 283.

[10] Bigumandondera, P. (2014) Study of Non-Collective Sanitation in Sub-Saharan Africa: Application to the City of Bujumbura. Ph.D. Thesis, Faculty of Sciences Sanitation and Environment Unit, University of Liège, 13.

[11] Leila, M. (2014) Etude de faisabilité de l'installation de station d'épuration des rejets urbains par les filtres plantés en milieu aride—Application à la région de Biskra. Faculté des Sciences et de la technologie, Université Mohamed Khider, Biskra, 134.

[12] Nsavyimana, G. (2014-2015) Modelling of Physical and Biological Processes in Septic Tanks and Routes for Recovering Sludge Drainage: Application in Bujumbura-Burundi. Faculty of Science, University of Liege, 1078.

[13] Iwema, A., Dominique, R., Jacques, L., Catherine, B., Drik, E., *et al.* (2005) Treatment of Domestic Wastewater by Filters Planted with Macrophytes. Technical Recommendations for Design and Construction, Version No. 1, 18-29.

[14] Yaichi, M., Mammeri, A. and Fellah, M.-K. (2016) Monitoring and Evaluation of PV Pumping System Performance Installed in the Algeria's Sahara City of Adrar. *International Journal on Electrical Engineering and Informatics*, **8**, 253-267. https://doi.org/10.15676/ijeei.2016.8.2.2

[15] Djeddou, M., Achour, B. and Martaud, M. (2013) Determination of the Daily Level of Reliability in a Municipal Wastewater Treatment Plant. *The 4th International Congress Water, Waste and Environment* (*EDE4*), Agadir, Morocco, 18-20 December, 1-2.

[16] Lombard-Latune, R., Pelusb, L., Finac, N., *et al.* (2018) Resilience and Reliability of Compact Vertical-Flow Treatment Wetlands Designed for Tropical Climates. *Science of the Total Environment*, **642**, 208-215. https://doi.org/10.1016/j.scitotenv.2018.06.036

[17] Molle, P., Fournel, J., Meyer, D., *et al.* (2013) Extensive Systems for the Management and Treatment of Urban Water during Rainy Weather. Technical guide, 43, hal-02599141.

[18] Fonkou, T., Fouteh, M.F., Djousse Kanouo, M. and Akoa, A. (2010) Performances of Vegetated Beds with *Echinochloa pyramidalis* in the Purification of Wastewater from Distillery in Sub-Saharan Africa. *Tropicultura*, **28**, 76.

[19] Franceys, R., Pickford, J. and Reed, R. (1995) Guide to Personal Sanitation. World Health Organization (WHO), Geneva, 258.

[20] Kone, M., Bonou, L., Koulidiati, J., Joly, P., Sodre, S. and Bouvet, Y (2012) Treatment of Urban Wastewater by Infiltration Percolation on Sand and on Coconut Substrate after an Anaerobic Lagoon Basin in a Tropical Climate. *Journal of Water Sciences*, **25**, 40-141. https://doi.org/10.7202/1011604ar

[21] Morvannou, A., Forquet, N., Michel, S., Troesch, S. and Molle, P. (2015) Treatment Performances of French Constructed Wetlands: Results from a Database Collected over the Last 30 Years. *Water Science and Technology*, **71**, 1333-1339. https://doi.org/10.2166/wst.2015.089

[22] Boutin, C., Esser, D., Molle, P. and Lienard, A. (2000) Filters and Beds Planted with Reeds for Treatment of Domestic Wastewater. Prospects for the Treatment of Rainwater. Communication in a Congress, Environmental Science, France, hal-00508350, 1-19.